

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
19 September 2002 (19.09.2002)

PCT

(10) International Publication Number
WO 02/073817 A1(51) International Patent Classification⁷: **H04B 1/12**(74) Agent: **KOLSTER OY AB**; Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).(21) International Application Number: **PCT/FI02/00148**

(22) International Filing Date: 22 February 2002 (22.02.2002)

(25) Filing Language: **Finnish**(26) Publication Language: **English**(30) Priority Data:
20010367 23 February 2001 (23.02.2001) **FI**(71) Applicant (for all designated States except US): **NOKIA CORPORATION [FI/FI]**; Keilalahdentie 4, FIN-02150 Espoo (FI).

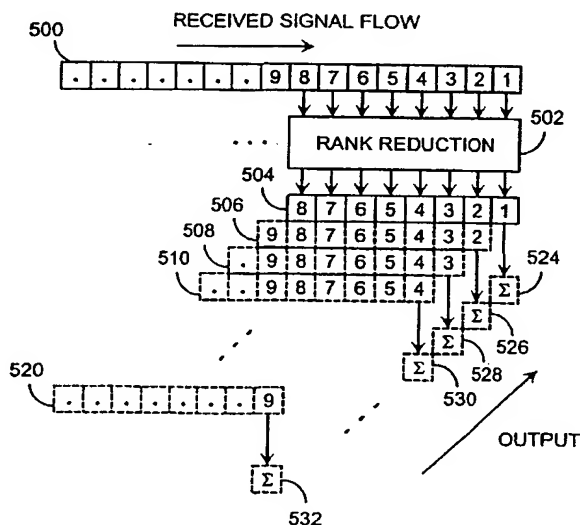
(72) Inventor; and

(75) Inventor/Applicant (for US only): **HENTTU, Pertti [FI/FI]**; Kaivosojantie 83, FIN-90470 Varjakka (FI).

(81) Designated States (national): AE, AG, AL, AM, AT (utility model), AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ (utility model), CZ, DE (utility model), DE, DK (utility model), DK, DM, DZ, EC, EE (utility model), EE, ES, FI (utility model), FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK (utility model), SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: **METHOD AND ARRANGEMENT FOR INTERFERENCE ATTENUATION**

(57) Abstract: A method of attenuating interference in a wideband telecommunications system comprises setting an interference level threshold; sampling the received signal; storing the sample values as first sample value vectors of a 5 predetermined length, forming prediction matrices of the first sample value vectors; modifying prediction matrices in such a way that the interference components and the components of the desired signal are separated from each other; forming signal matrices by performing rank reduction for each prediction matrix by rejecting those sample values or elements representing 10 them that exceed the interference level threshold; forming second sample value vectors of the signal matrices, the second sample value vectors being at least substantially of the same length as the first sample value vectors; summing up sample values of second sample value vectors time-coherently to average the noise by sliding the sample value window, the length of which is 15 determined preferably by the length of the first sample value vectors.

**Declarations under Rule 4.17:**

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

— *of inventorship (Rule 4.17(iv)) for US only*

Published:

- *with international search report*

(48) Date of publication of this corrected version:

28 November 2002

(15) Information about Correction:

see PCT Gazette No. 48/2002 of 28 November 2002, Section II

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
19 September 2002 (19.09.2002)

PCT

(10) International Publication Number
WO 02/073817 A1

(51) International Patent Classification⁷: **H04B 1/12**

(21) International Application Number: **PCT/FI02/00148**

(22) International Filing Date: **22 February 2002 (22.02.2002)**

(25) Filing Language: **Finnish**

(26) Publication Language: **English**

(30) Priority Data:
20010367 23 February 2001 (23.02.2001) FI

(71) Applicant (for all designated States except US): **NOKIA CORPORATION [FI/FI]; Keilalahdentie 4, FIN-02150 Espoo (FI).**

(72) Inventor; and

(75) Inventor/Applicant (for US only): **HENTTU, Pertti [FI/FI]; Kaivosojantie 83, FIN-90470 Varjakka (FI).**

(74) Agent: **KOLSTER OY AB; Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).**

(81) Designated States (national): **AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EC, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.**

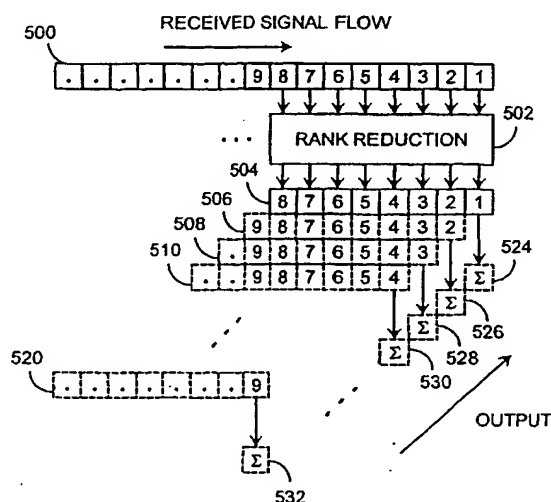
(84) Designated States (regional): **ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).**

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA,*

[Continued on next page]

(54) Title: **METHOD AND ARRANGEMENT FOR INTERFERENCE ATTENUATION**



(57) Abstract: A method of attenuating interference in a wideband telecommunications system comprises setting an interference level threshold; sampling the received signal; storing the sample values as first sample value vectors of a 5 predetermined length, forming prediction matrices of the first sample value vectors; modifying prediction matrices in such a way that the interference components and the components of the desired signal are separated from each other; forming signal matrices by performing rank reduction for each prediction matrix by rejecting those sample values or elements representing 10 them that exceed the interference level threshold; forming second sample value vectors of the signal matrices, the second sample value vectors being at least substantially of the same length as the first sample value vectors; summing up sample values of second sample value vectors time-coherently to average the noise by sliding the sample value window, the length of which is 15 determined preferably by the length of the first sample value vectors.



CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations
- of inventorship (Rule 4.17(iv)) for US only

Published:

- with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD AND ARRANGEMENT FOR INTERFERENCE ATTENUATION

FIELD OF THE INVENTION

[0001] The invention relates to a method and an arrangement for interference attenuation in a wideband telecommunications system.

BACKGROUND OF THE INVENTION

[0002] On the radio path, both AWGN, i.e. additive white gaussian noise, and different interference signals or fading multipath-propagated signal components of different signals are summed up in the desired signal. Interferences are usually caused inadvertently by other systems or other users of the same system, but they can also be caused deliberately. There have been attempts to eliminate or attenuate interferences with for instance different coding-decoding methods, channel equalizers and filtering. However, it has been problematic to find a sufficiently efficient noise-attenuation method that would be applicable to wideband telecommunications systems. The problem has specifically been to find such a method that would efficiently attenuate also relatively wideband interference in wideband data transmission systems.

[0003] Singular value decomposition, i.e. SVD, refers to numeric signal processing applied to several objects of use, such as spectral analysis, design of filters, and reduction and estimation of model orders. Singular value decomposition can be applied directly to processing data matrices, and it is applicable to both real and complex value matrices. Singular value decomposition is described in more detail in publication by Todd K. Moon, Wynn C. Stirling: *Mathematical Methods and Algorithms for Signal Processing*, Prentice Hall, 2000, which is incorporated as reference herein.

BRIEF DESCRIPTION OF THE INVENTION

[0004] An object of the invention is to implement an improved method of attenuating particularly such interference that is not previously known. This is achieved with a method of attenuating interference in a wideband telecommunications system. The method comprises setting an interference level threshold; sampling the received signal; storing the sample values as first sample value vectors of a predetermined length, forming prediction matrices of the first sample value vectors; modifying prediction matrices in such a way that the interference components and the components of the desired signal are separated from each other; forming signal matrices by

performing rank reduction for each prediction matrix by rejecting those sample values or elements representing them that exceed the interference level threshold; forming second sample value vectors of the signal matrices, the second sample value vectors being at least substantially of the same length as the first sample value vectors; summing up sample values of second sample value vectors time-coherently to average the noise by sliding the sample value window, the length of which is determined preferably by the length of the first sample value vectors.

[0005] Further, an object of the invention is a receiver in a wideband telecommunications system, implementing the method, interference being attenuated in the receiver. The receiver comprises means for setting an interference level threshold; the receiver comprises means for sampling the received signal; the receiver comprises means for storing the sample values as first sample value vectors of a predetermined length; the receiver comprises means for forming prediction matrices of the first sample value vectors; the receiver comprises means for modifying prediction matrices in such a way that the interference components and the components of the desired signal are separated from each other; the receiver comprises means for forming signal matrices by performing rank reduction for each modified prediction matrix by rejecting those sample values or elements representing them that exceed the interference level threshold; the receiver comprises means for forming second sample value vectors of the signal matrices, the second sample value vectors being at least substantially of the same length as the first sample value vectors; the receiver comprises means for summing up sample values of second sample value vectors time-coherently to average the noise by sliding the sample value window, the length of which is determined preferably by the length of the first sample value vectors.

[0006] Preferred embodiments of the invention are disclosed in the dependent claims.

[0007] The invention is based on the idea that the sample values taken from the received signal are stored as vectors of a desired length, of which data matrices are formed, being called prediction matrices. The prediction matrices are modified in such a way that the interference components and the components of the desired signal are separated from each other. This can be implemented for example by factorizing the matrix by means of singular value decomposition. Next, those sample values, elements

representing the sample values or, in the case of signal value decomposition, singular values and corresponding singular vectors that exceed the set interference level threshold are rejected. In this way, rank reduction is preferably performed for the matrix in accordance with the Eckhart-Young theorem. Next, new sample value vectors are formed using the remaining values. In this way, interference summed up in the signal in the channel can be attenuated. Finally, noise is averaged by adding up sample values in a time-coherent manner.

[0008] A plurality of advantages is achieved with the method and system according to the invention. Interference in a receiver of a wideband system can be efficiently attenuated with the method of the invention. Relatively wideband interference not known in advance can also be removed by means of the method of the invention by determining a sliding sample value window to be of an appropriate size relative to the interfering system: with a narrow sample value window, the momentary relative bandwidth of the interference can be made narrow compared with the bandwidth of the desired signal.

BRIEF DESCRIPTION OF THE FIGURES

[0009] The invention will now be described in greater detail in connection with preferred embodiments, with reference to the attached drawings, in which

[0010] Figure 1 shows an example of a telecommunications system;

[0011] Figure 2 shows a second example of a telecommunications system;

[0012] Figure 3 shows a flow chart of the method steps for attenuating interference in a wideband telecommunications system;

[0013] Figure 4 illustrates an example of rank reduction in the matrix;

[0014] Figure 5 illustrates an example of averaging noise;

[0015] Figure 6 shows an example of a receiver;

[0016] Figure 7 shows an example of a simulation result.

DESCRIPTION OF EMBODIMENTS

[0017] The solution according to the invention is particularly applicable to the MC-CDMA (Multi Carrier Code Division Multiple Access) radio system utilizing direct sequence (DS) technique. Other objects of application

can include satellite systems, military telecommunications systems and private non-cellular networks. The solution according to the invention is not confined to these, however.

[0018] The following example illustrates preferred embodiments of the invention in the UMTS (Universal Mobile Telephone System) without, however, restricting the invention thereto.

[0019] The structure of a mobile system is described with reference to Figure 1. The main parts of the mobile system are a core network CN, a UMTS terrestrial radio access network UTRAN and user equipment Ue. The interface between the CN and the UTRAN is called Iu, the interface between the UTRAN and the Ue being called Uu.

[0020] UTRAN is formed of radio network subsystems RNS. The interface between the RNSs is called Iur. The RNS is formed of a radio network controller RNC and of one or more nodes B. The interface between the RNC and B is called Iub. The coverage area of the node B, i.e. the cell, is denoted by C in the figure.

[0021] The description shown in Figure 1 is at rather a general level so that Figure 2 shows a more detailed example of a cellular radio network. Figure 2 contains only the most essential blocks, but it will be obvious to a person skilled in the art that a conventional cellular radio network also includes other functions and structures, the more detailed description of which is not necessary herein. The details of the cellular radio network may deviate from those shown in Figure 2, but with regard to the invention, these differences have no significance.

[0022] Thus, the cellular radio network typically comprises the infrastructure of a fixed network, i.e. a network part 200, and user equipment units 202, which can be fixedly positioned, positioned in a vehicle, or portable terminals, such as mobile phones or portable computers that allow a connection to a radio telecommunications system. The network part 200 comprises base stations 204. The base station corresponds to the node B in the preceding figure. A radio network controller 206 connected to the base stations, in turn, controls several base stations 204 in a centralized manner. The base station 204 comprises transceivers 208 and a multiplexer unit 212.

[0023] The base station 204 further comprises a control unit 210 which controls the operation of the transceiver 208 and the multiplexer 212. By means of the multiplexer 212, the traffic and control channels used by several

transceivers 208 are positioned on one transmission link 214. The transmission link 214 forms the interface lub.

[0024] There is a connection from the transceiver 208 of the base station 204 to an antenna unit 218, by means of which a radio connection 216 is implemented to the user equipment 202. In the radio connection 216, the structure of the frames to be transferred is determined in a system-specific manner and is called an air interface Uu.

[0025] The radio network controller 206 comprises a group-switching network 220 and a control unit 222. The group switching network 220 is used for switching speech and data and for connecting signalling circuits. A radio network subsystem 224 formed by the base station 204 and the radio network controller 206 further comprises a transcoder 226. The transcoder 226 is usually positioned as close to the mobile services switching centre 228 as possible, because speech can then be transmitted between the transcoder 226 and the radio network controller 206 in the form of a cellular radio network in such a way that transmission capacity is saved.

[0026] The transcoder 226 converts the different digital speech coding modes used between the public switched telephone network and the mobile telephone network to be compatible with each other, for example from the fixed-network mode into another mode of a cellular radio network, or vice versa. The control unit 222 performs call control, mobility management, collection of statistical data and signalling.

[0027] Figure 2 further illustrates a mobile services switching centre 228 and a gateway mobile services switching centre 230, which is responsible for the connections of the mobile telephone system to the outside world, in this case to a public switched telephone network 232.

[0028] Figure 3 shows a flow chart of the method steps for attenuating interference in a wideband telecommunications system, such as in WCDMA systems. The method is applicable to removing interference of many types in wideband systems by adjusting the width of the sample window used in the method. In one embodiment of the method, interference attenuation is performed separately for each sample vector, so that the method can also be applied to a parallel interference attenuation arrangement.

[0029] Performing the method starts from a block 300. In a block 302, an interference level threshold is set. The interference level threshold can be set in advance, or the interference level threshold can be changed.

Determination of the interference level threshold can be based on for example measurements performed in the network, advance information on the interfering system or the aim set for the bit error ratio. For instance, if the interfering system is frequency-hopping, the interference level of the channel can be measured when it is known that the interference signal is not on this particular frequency band, and then the interference level threshold can be set according to the measurement results received.

[0030] In a block 304, the received signal is sampled by means of a method according to the prior art. The received signal is composed of a desired signal, noise and interference. The sampling frequency is preferably one sample per chip, i.e. symbol of a spreading code. If the sampling frequency is something else, the samples can be stored in a buffer memory.

[0031] In a block 306, the baseband sample values are stored as first sample value vectors of a predetermined length. The length of the sample value vectors can be selected freely to be suitable for each system.

[0032] In a block 308, a prediction matrix is formed of each sample value vector. In the following, one possible example of forming one prediction matrix is described when 8 samples have been taken from the received signal, in other words when the length of the sample value vector is 8. The first line in the matrix contains samples 1 to 6 of each sample value vector, the next one containing samples 2 to 7 and the third one containing samples 3 to 8. Thus, the sample vector is slid forwards sample by sample until all elements of one sample vector have been positioned in the matrix. After this, the complex conjugate values are positioned in the matrix in the reverse order, i.e. at first the complex conjugate values of the samples 6 to 1, the complex conjugate values of the samples 7 to 2 on the next line, and the complex conjugate values of the samples 8 to 3 on the last line. This yields the following matrix as the prediction matrix A

$$\text{[0033]} \quad A = \begin{bmatrix} r(1) & r(2) & r(3) & r(4) & r(5) & r(6) \\ r(2) & r(3) & r(4) & r(5) & r(6) & r(7) \\ r(3) & r(4) & r(5) & r(6) & r(7) & r(8) \\ \bar{r}(6) & \bar{r}(5) & \bar{r}(4) & \bar{r}(3) & \bar{r}(2) & \bar{r}(1) \\ \bar{r}(7) & \bar{r}(6) & \bar{r}(5) & \bar{r}(4) & \bar{r}(3) & \bar{r}(2) \\ \bar{r}(8) & \bar{r}(7) & \bar{r}(6) & \bar{r}(5) & \bar{r}(4) & \bar{r}(3) \end{bmatrix}. \quad (1)$$

[0034] In a block 310, the prediction matrices are modified in such a way that the interference components and the desired-signal components are separated from each other. This can be implemented by, for example, diagonalization or factorization of the matrix. The diagonalization can be implemented for instance by means of eigendecomposition, which is, however, applicable to square matrices only. Factorization can preferably be implemented by means of singular value decomposition (SVD). With singular value decomposition, the data matrix can be divided into factors, from which interference compositions and desired-signal compositions can be separated. SVD is applicable to all kinds of matrices, also other than square matrices. By means of singular value decomposition, the matrix A can be presented as follows

$$[0035] \quad A = U \Sigma V^* \quad (2)$$

[0036] where matrices U and V are unitary matrices and Σ is a diagonal matrix comprising singular matrices of the matrix A. In general, the singular values are in a descending order. The asterisk denotes a complex conjugate transpose of the matrix. The 6X6 matrix in the exemplary case yields singular decomposition in which all matrices U, V and Σ are 6X6 matrices.

[0037] In a block 312, signal matrices are formed by performing rank reduction for each modified prediction matrix by rejecting the sample values, the elements representing them or the singular values that exceed the set interference level threshold. The rank reduction can be performed by utilizing the Eckhart-Young theorem, which yields the best least square estimate of the desired signal.

[0038] In the following, the rank reduction of the matrix is explained with reference to the example of Figure 4. Figure 4 shows an example of a typical case, where a wideband system is disturbed by a system which is narrowband in comparison and the power of which is significantly higher than that of the wideband system. The figure shows samples taken from the received signal or elements representing the samples when the interference components and desired-signal components have been separated from each other and shown in the order of magnitude. If the factorization of the matrix has been performed with singular value decomposition, the values in the diagonal form are called singular values. The vertical axis indicates the power or amplitude values, the horizontal axis indicating the samples or elements in the order of magnitude. In Figure 4, the samples, elements or singular values 404,

406, 408, 410, 412, 414, 416 comprising only a little or no interference are below the set interference level threshold 400; in other words these samples, elements or singular values contain only desired signal or white gaussian noise. By contrast, a sample, element or singular value 402 exceeding the interference level threshold also contains an interference signal that is at least relatively powerful. Thus, the sample, element or singular value 402 is rejected. In accordance with the Eckhart-Young theorem, this sample value or element is rejected from the matrix Σ , the corresponding columns being rejected from the matrices U and V. A more detailed example of the application of the Eckhart-Young theorem is described in publication by Pertti Henttu, Ari Pouttu: *'Blind SVD Based Interference Suppressor in Spread Spectrum Communications'*, which is incorporated as reference herein.

[0039] The prediction matrix of the desired signal according to the Eckhart-Young is in the form

$$[0040] \hat{A} = \sum_{k=1}^{r_s} \sigma_k u_k v_k^* \quad (3)$$

[0041] where r_s is the greatest singular value index, which singular value belongs to the estimate of the desired signal.

[0042] In a block 314, new sample value vectors are formed of the signal matrices by summing up the sample values or elements of the matrix \hat{A} with the corresponding complex conjugates. Thus, in the case of the matrix shown in Formula (1), the sample value estimate \hat{r}_1 yields the value

$$[0043] \hat{r}(1) = \hat{A}(1,1) + \hat{A}(4,6)^* \quad (5)$$

[0044] and the sample estimate \hat{r}_2 yields

$$[0045] \hat{r}(2) = \hat{A}(1,2) + \hat{A}(2,1) + \hat{A}(4,5)^* + \hat{A}(5,6)^* \quad (6)$$

[0046] Other sample value estimates are determined correspondingly. New sample value vectors are formed of the sample value estimates. The above method is preferably repeated for all original sample value vectors.

[0047] In a block 316, sample values of second, i.e. new, sample value vectors are summed up to average the interference in a time-coherent manner by sliding the sample value window, the length of which sample value window is preferably determined by the length of first, i.e. the original, sample value vectors. The window is slid by one or more sample values at a time. The size of the sliding step is determined according to each application. In this way, an estimate sampled by means of new sample value vectors can be formed of the received signal, from which at least samples with strong interference have been filtered out and from which the effect of noise has been averaged out.

[0048] Figure 5 illustrates an example of noise averaging by sliding the sample value window. Figure 5 shows, by way of example, only part of the sample value vectors. A sample sequence 500 shows successive samples taken from the received signal. The samples 500 are preferably stored at first in the form of a vector and after that in the form of a matrix for the purpose of diagonalization and rank reduction. The dimensions of the matrices in the example of Figure 5 are 8X8. The rank reduction of the matrix is performed in a block 502. After the rank reduction, new sample value vectors are formed which comprise samples of a signal with noise. The sample value vectors of Figure 5 have been formed in accordance with the method described above. A first element 524 of the interference-attenuated and noise-attenuated estimate vector of the received signal is a sample of a sample vector 504, taken at the moment of time 1. A second element 526 of the interference-attenuated and noise-attenuated estimate-vector of the received signal is the sum of the samples of sample vectors 504 and 506, taken at the moment of time 2; a third element 528 is the sum of the samples of sample vectors 504, 506 and 508, taken at the moment of time 3; and a fourth element 530 is the sum of the samples of sample vectors 504, 506, 508 and 510, taken at the moment of time 4. The method is repeated for the next sample block. In Figure 5, this is illustrated by a ninth element 532 of the estimate vector, which is received by calculating the sum of the samples of sample vectors 506, 508, 510,..., 520, taken at the moment of time 9. The sample vectors 504, 506, 508, 510,..., 520 can be supplemented with new samples by means of a continuous process, or the samples can be treated block-specifically.

[0049] The method illustrated by the flow chart of Figure 3 can be implemented in a plurality of ways, of which the figure shows two different alternatives. An arrow 318 shows the repeatability of the method as beginning

from the setting of the interference level threshold, and an arrow 320 indicates the repeatability of the method as beginning from the modification of the stored estimate matrices. The performance of the method is terminated in a block 322.

[0050] Next, an example of a receiver is described with reference to Figure 6. Figure 6 illustrates, for the sake clarity, a simplified example of a receiver at a block diagram level by means of one embodiment. It will be obvious to a person skilled in the art that a transceiver can also comprise parts other than the ones shown in Figure 6. The receiver shown can be positioned for instance in the base station of a radio system, in a portable communication device, such as a telephone or a handheld computer or another corresponding device.

[0051] The receiver comprises an antenna or an antenna array 600 consisting of antenna elements, and RF (Radio Frequency) parts 602 in which the received signal is filtered, down-converted either directly to the baseband frequency or to intermediate frequency, and amplified. Measurements possibly performed to set the interference level threshold can also be performed in the block 602. In a block 604, the signal is converted from analogue into digital by sampling and quantizing. An estimate of the received signal according to the above-described embodiment, from which interference has been attenuated, is formed in a block 606. In this exemplary case, the block 606 also comprises the memory required for storing the signal sample values. The memory block can also be separate. A block 608 comprises a filter matched with the duration of a chip, i.e. a symbol of a spreading code, the filter being also used in code search. The filter matched with the chip of the block 608 can also be positioned before the block 606. In a block 610, a direct-spread wideband signal is despread by filtering it by means of a filter arranged in the spreading code, which filter is used in signal detection and synchronization. In a block 612, the signal is demodulated, and bit decisions are made. The bit decisions can be either hard decisions or soft decisions. A block 614 comprises required signal processing, such as deinterleaving, decoding and decryption.

[0052] In a preferred embodiment, the receiver, such as a multi-finger receiver of a RAKE type, comprises a delay estimator by means of which the delays of the multipath-propagated components are estimated. The delays of the different RAKE fingers are set to correspond to the delays of the signal components delayed in different ways.

[0053] The invention is preferably implemented by software, in which case the terminal comprises one or more microprocessors, the functions according to the described interference attenuation method being implemented by software operating in the microprocessor(s). The invention can also be implemented by hardware solutions providing the required functionality, for instance by utilizing the ASIC (Application Specific Integration Circuit) or separate logic components. It is also to be noted that the method enables the use of parallel processing.

[0054] Figure 7 illustrates an example of simulation results of the above-described interference attenuation method. Figure 7 shows curves of the bit error ratio. The vertical axis shows the number of incorrect bits of all received bits, and the horizontal axis shows the ratio of the received bit energy to the noise energy. The simulated system is a DS/FS system, i.e. a direct sequence frequency hopping system. The length of the spreading code is 63 chips and the modulation method is BPSK (binary phase shift keying). The length of the frequency hopping is 100 bits. The interfering signal is also frequency-hopping, and its intermediate frequency is converted hop by hop. The interfering signal is a square pulse BPSK signal (SQ BPSK). A curve 700 describes performance of one of the interference attenuations according to the prior art. The method used is an RLS (Recursive Least Squares) filter. A curve 702 describes performance of one embodiment of the above-described interference attenuation method when the length of the received signal block is 5 samples; a curve 704 describes performance of one embodiment of the above-described interference attenuation method when the length of the received signal block is 8 samples; a curve 706 describes performance of one embodiment of the above-described interference attenuation method when the length of the received signal block is 11 samples.

[0055] Figure 7 shows that the performance of the interference attenuation method according to one embodiment of the invention is better than that of the prior art system, particularly when the signal-noise ratio increases. The figure also shows that changing the length of the received signal block to be processed, and at the same time, changing the length of the sample window can affect the performance of the method. The length of the sample block giving the best performance depends on both the system that is the object of interference and the interfering system.

[0056] Although the invention is described above with reference to the example according to the attached drawings, it will be obvious that the invention is not restricted thereto but can be modified in a plurality of ways within the inventive idea of the attached claims.

CLAIMS

1. A method of attenuating interference in a wideband telecommunications system,

characterized by

302 setting an interference level threshold;

304 sampling the received signal;

306 storing the sample values as first sample value vectors of a predetermined length,

308 forming prediction matrices of the first sample value vectors;

310 modifying prediction matrices in such a way that the interference components and the components of the desired signal are separated from each other;

312 forming signal matrices by performing rank reduction for each prediction matrix by rejecting those sample values or elements representing them that exceed the interference level threshold;

314 forming second sample value vectors of the signal matrices, the second sample value vectors being at least substantially of the same length as the first sample value vectors;

316 summing up sample values of second sample value vectors time-coherently to average the noise by sliding the sample value window, the length of which is determined preferably by the length of the first sample value vectors.

2. A method according to claim 1, **characterized** by the interference level threshold being solid.

3. A method according to claim 1, **characterized** by the interference level threshold being changeable.

4. A method according to claim 1, **characterized** by the interference level threshold being set on the basis of measurements performed of the channel.

5. A method according to claim 1, **characterized** by the length of the sample value vectors being determined by the length of the spreading code.

6. A method according to claim 1, **characterized** by the prediction matrices being formed by means of the sample value vectors and their complex conjugates.

7. A method according to claim 1, **characterized** by the rank reduction of the matrix being performed by utilizing the Eckhart-Young theorem.

8. A method according to claim 1, **characterized** by the sample value window being slid by one or more sample values at a time.

9. A method according to claim 1, **characterized** by the separation of the interference components and the desired-signal components being performed by diagonalization.

10. A method according to claim 1, **characterized** by the separation of the interference components and the desired-signal components being performed by factorization.

11. A receiver in a wideband telecommunications system, in which receiver interference is attenuated,

characterized in that

the receiver comprises means (602, 603) for setting an interference level threshold;

the receiver comprises means (604) for sampling the received signal;

the receiver comprises means (606) for storing the sample values as first sample value vectors of a predetermined length;

the receiver comprises means (606) for forming prediction matrices of the first sample value vectors;

the receiver comprises means (606) for modifying prediction matrices in such a way that the interference components and the components of the desired signal are separated from each other;

the receiver comprises means (606) for forming signal matrices by performing rank reduction for each modified prediction matrix by rejecting those sample values or elements representing them that exceed the interference level threshold;

the receiver comprises means (606) for forming second sample value vectors of the signal matrices, the second sample value vectors being at least substantially of the same length as the first sample value vectors;

the receiver comprises means (606) for summing up sample values of second sample value vectors time-coherently to average the noise by sliding the sample value window, the length of which is determined preferably by the length of the first sample value vectors.

12. A receiver according to claim 11, **characterized** in that the interference level threshold is fixed.

13. A receiver according to claim 11, **characterized** in that the interference level threshold is changeable.

14. A receiver according to claim 11, **characterized** in that the interference level threshold is set on the basis of the measurements performed of the channel.

15. A receiver according to claim 11, **characterized** in that the length of the sample value vectors is determined by the length of the spreading code.

16. A receiver according to claim 11, **characterized** in that the prediction matrices are formed by means of sample value vectors and their complex conjugates.

17. A receiver according to claim 11, **characterized** in that the rank reduction of the matrix is performed by utilizing the Eckhart-Young theorem.

18. A receiver according to claim 11, **characterized** in that the sample value window is slid by one or more sample values at a time.

19. A receiver according to claim 11, **characterized** in that the separation of the interference components and the desired-signal components is performed by diagonalization.

20. A receiver according to claim 11, **characterized** in that the separation of the interference components and the desired-signal components is performed by factorization.

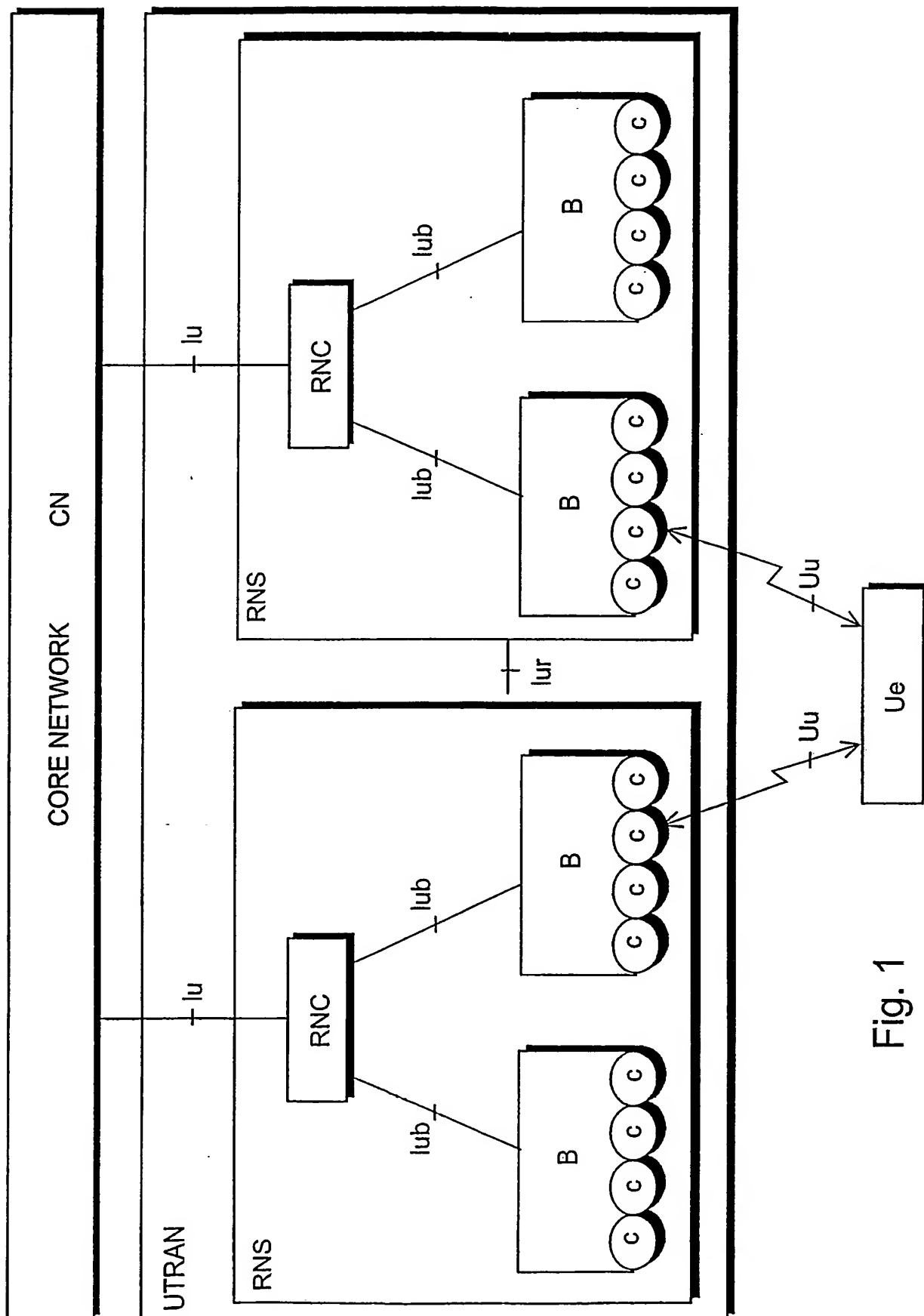


Fig. 1

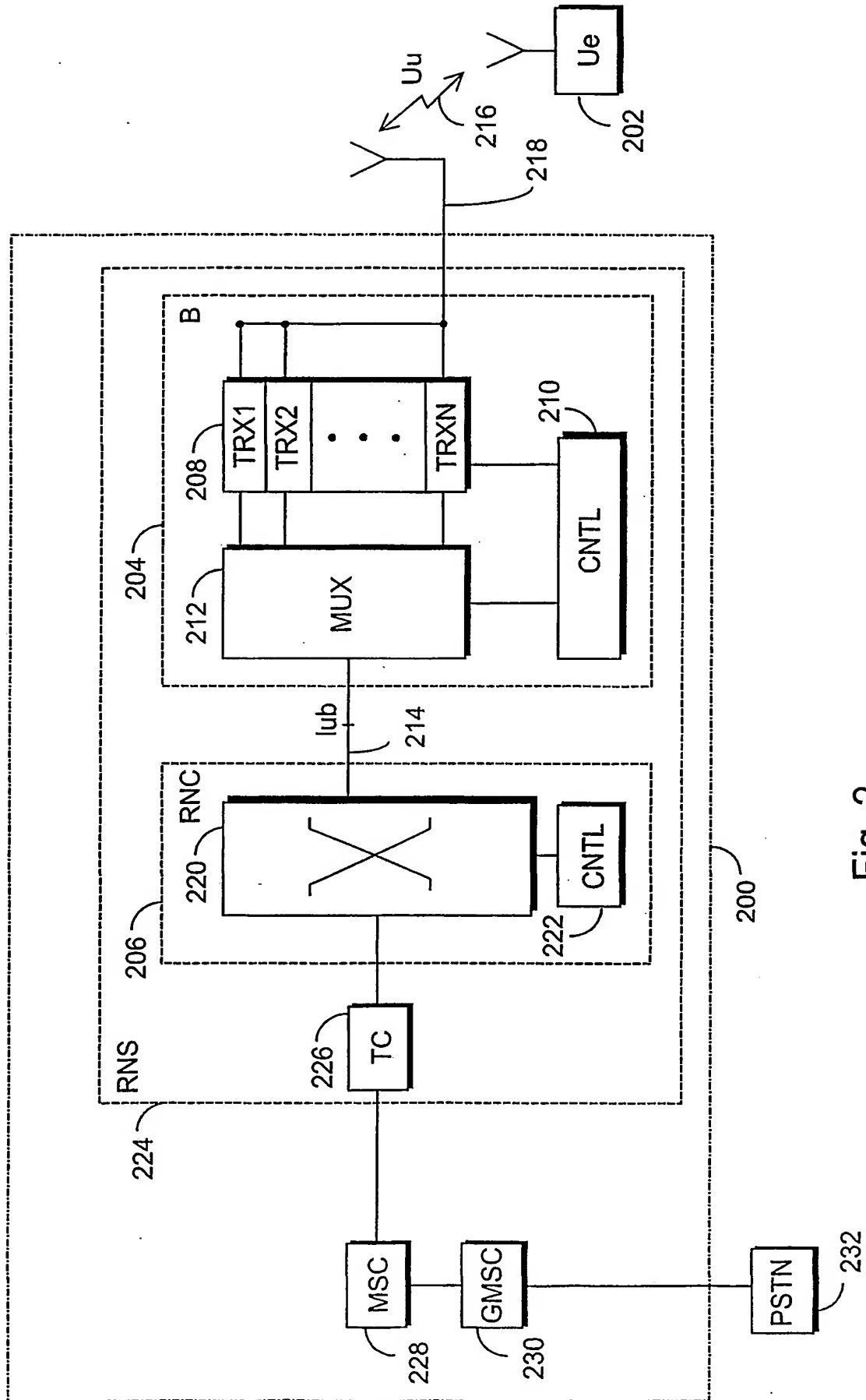
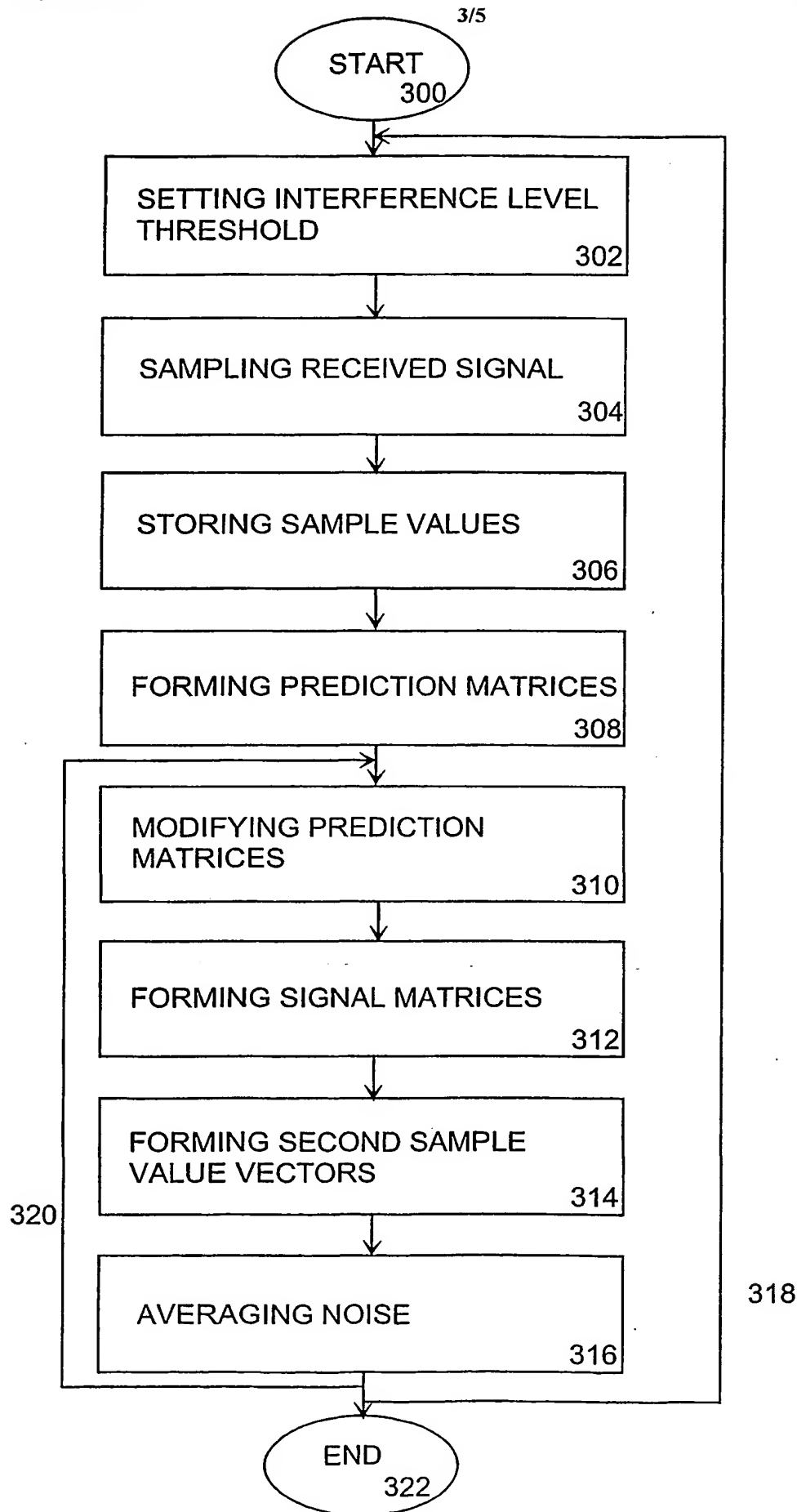


Fig. 2



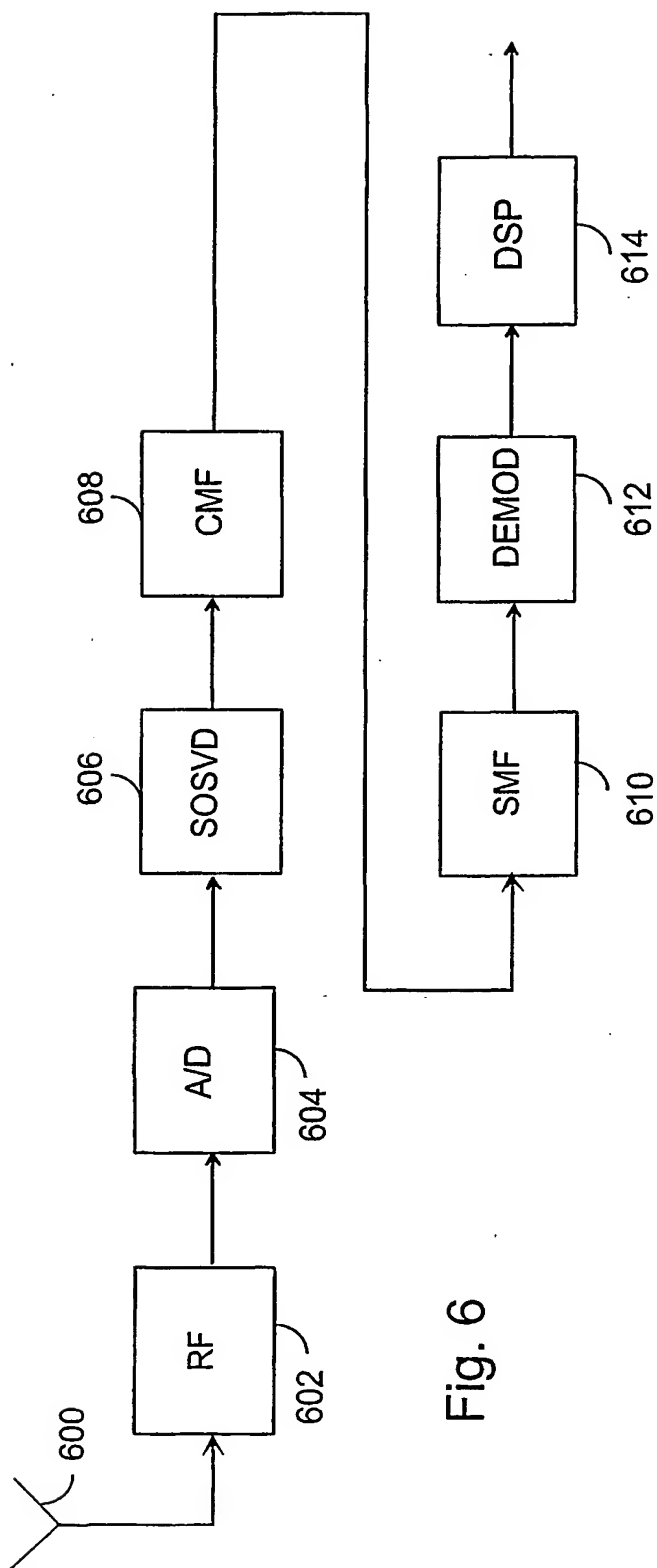


Fig. 6

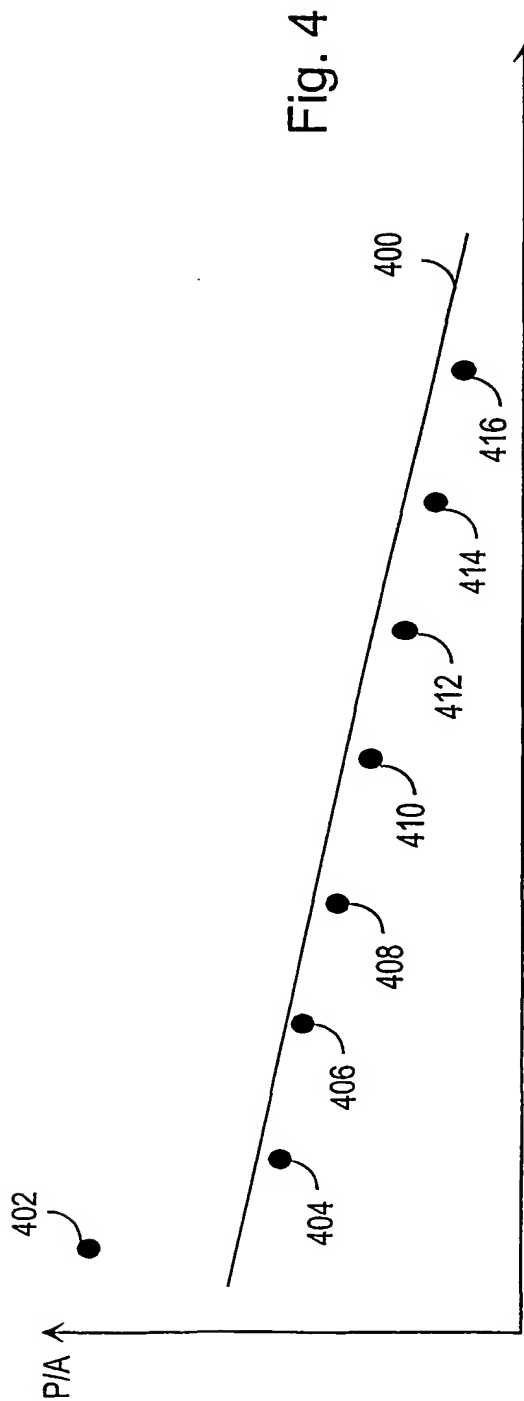


Fig. 4

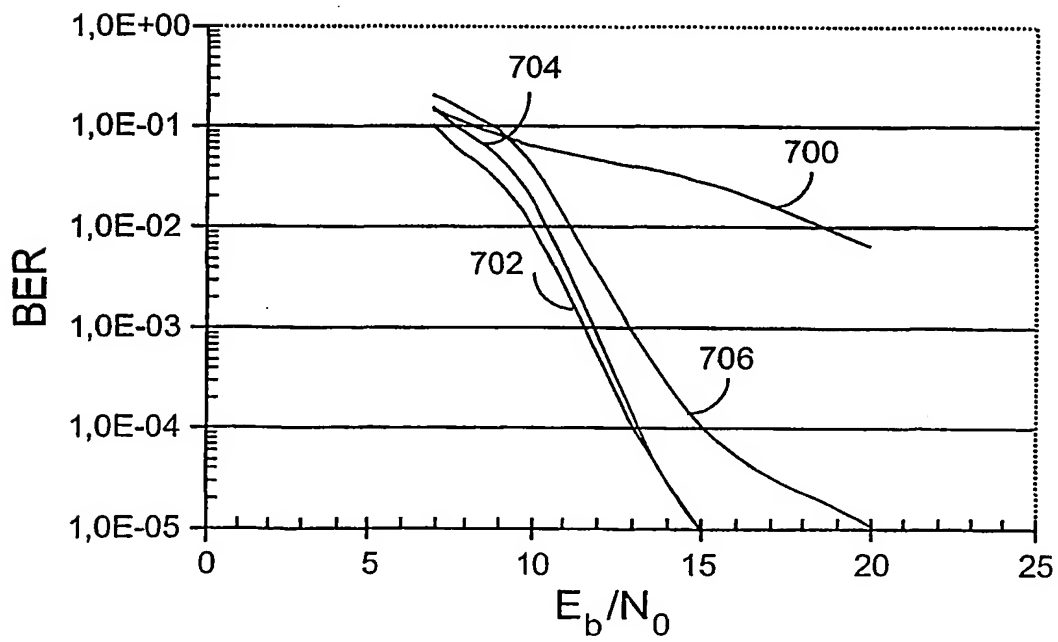
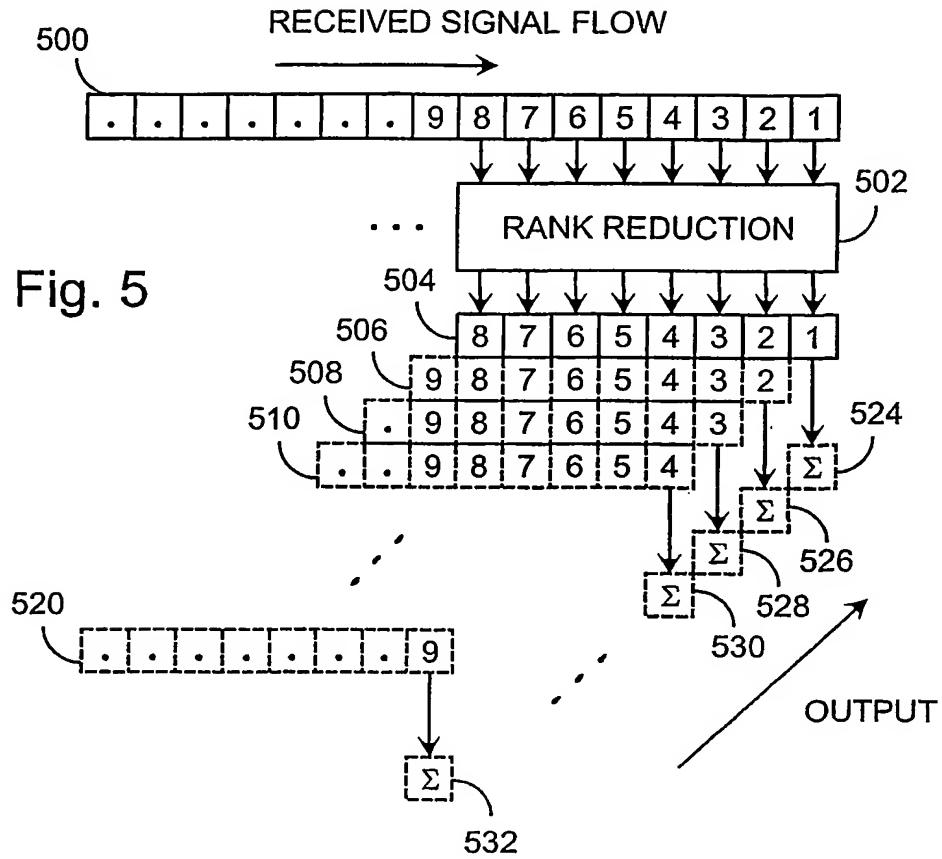


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 02/00148

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04B 1/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04B, H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	P. HENTTU, Cyclic SVD Method For Broadband Interference Cancellation in FH/DS communications, Sixth International Symposium on Spread Spectrum Techniques and Applications, 6-8 Sept. 2000, vol. 1, pages 68-72, ISBN: 0-7803-6560-7, see page 69 right col. - page 70 left col., figure 2, equation 6 --	1-20
X	P. HENTTU et al, Blind SVD Based Interference Suppressor in Spread Spectrum Communications, CISS'99 33rd Annual Conference on Information Sciences and Systems, Baltimore, Maryland, U.S.A, 17-19 March 1999, see section III --	1-20

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

4 June 2002

Date of mailing of the international search report

11-06-2002

Name and mailing address of the ISA/

Swedish Patent Office

Box 5055, S-102 42 STOCKHOLM

Facsimile No. +46 8 666 02 86

Authorized officer

Johanna Schyberg/AE

Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 02/00148

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E,X	P. HENTTU, Effective interference suppression using short overlapp regions of data and SVD. IEEE International Conference on Communications, 2002.ICC 2002. vol. 1, 28 April - 2 May 2002, pages 182 - 186, ISBN 0-7803-7400-2, see complete document --	1-20
A	EP 1077551 A1 (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.), 21 February 2001 (21.02.01), page 3, line 24 - line 29, figure 3 -- -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/05/02

International application No.

PCT/FI 02/00148

Patent document cited in search report				Publication date		Patent family member(s)		Publication date	
EP	1077551	A1	21/02/01	AU	2826500	A	28/09/00		
				CA	2328957	A	14/09/00		
				CN	1296683	T	23/05/01		
				JP	2000261412	A	22/09/00		
				WO	0054446	A	14/09/00		
